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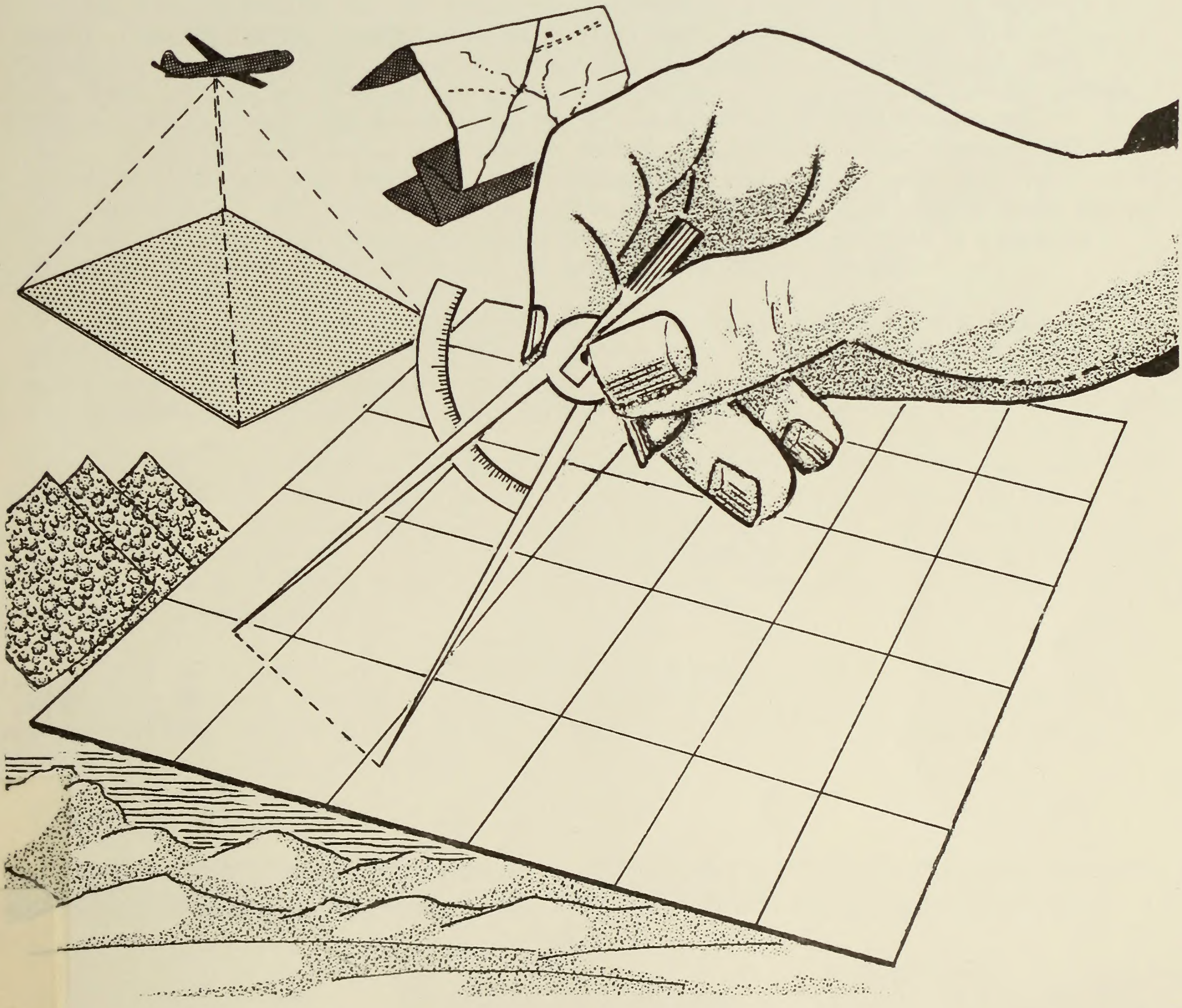
TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

THE USE OF AERIAL PHOTOGRAPHS

by Richard D. Burr
River Basin Studies



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INTRODUCTION

INTERPRETATION OF AERIAL PHOTOGRAPHS

This publication deals with aerial photographs and how they can be used in the various phases of land management within the Bureau. It is intended to furnish sufficient guidelines to encourage the use of aerial photos. Emphasis has been placed on basic data in this publication for its general application to phases of Bureau activity where aerial photos can be appropriately used.

The aerial photograph is the easiest way for us to examine an area in its entirety. Its unique information and overwhelming detail is to be found by no other source. It has revolutionized topographic mapping and brought new search techniques to such diverse fields as geology and archeology.

An aerial photograph is simply a photograph of the surface of the earth. It may approximate the normal view from an elevation but more likely it will have the unfamiliar view of the country directly below the airplane. It is surprising but true that the Bureau can make classifications of land with a high degree of accuracy by skilled photo-interpretation. Soils, building materials, and timber stands already are being accurately determined in the same manner. The increased tempo of work and necessity for programming well in advance of our activities might justifiably lead to preliminary investigations to define the work and to anticipate its nature in those areas where the workload is just beginning to expand.

Even the fact that a photograph grows old is of value. The record made by a photograph is so inclusive at the time it is taken that it becomes a valuable historical document and will serve as an excellent reference for measuring our progress and accomplishments on the land itself.

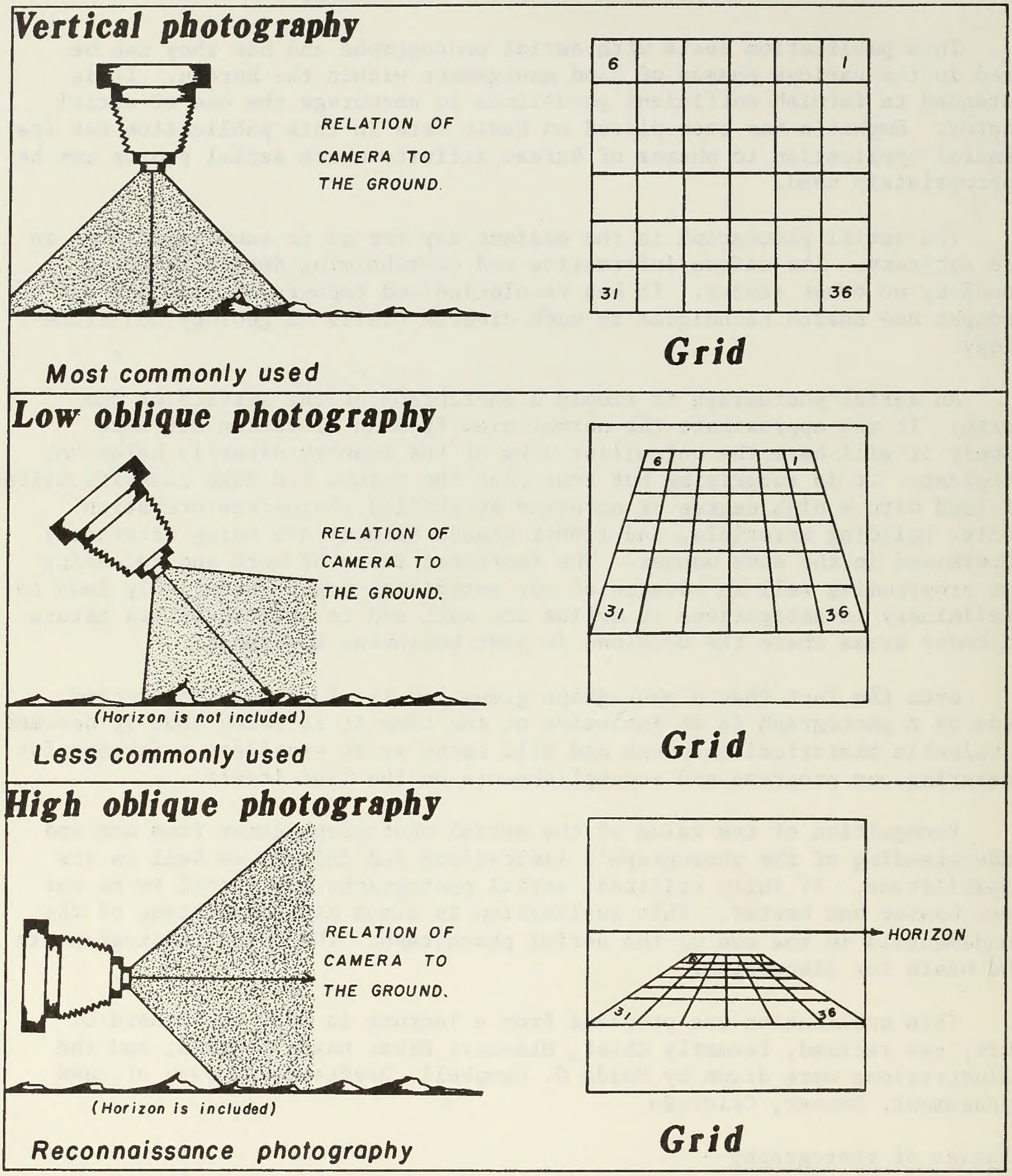
Recognition of the value of the aerial photograph comes from use and understanding of the photograph's limitations and defects as well as its capabilities. If fully utilized, aerial photographs are a tool to do our work easier and better. This publication is aimed at presentation of the fundamentals in the use of the aerial photograph. The single photograph is the basis for discussion.

This publication was prepared from a lecture in 1960 by Richard D. Burr, now retired, formerly Chief, Missouri River Basin Studies, and the illustrations were drawn by Maida G. Campbell, Draftsman, Bureau of Land Management, Denver, Colorado.

Classes of photography

Aerial photographs are classed according to their angle with the ground as vertical, low oblique and high oblique (Figure 1).

Types of aerial photography.



Figure···1

Vertical photographs

The vertical photograph is taken from an unfamiliar viewpoint directly below the airplane. This gives a map-like photograph of the earth's surface, however, it is not a map. The map-like qualities are emphasized only where the terrain is flat and level. A grid in that case will be relatively square and suitable planimetric maps can be prepared directly by overlays because corrections are easy. Distortions and displacements will require some corrections.

This is the commonly used photograph. All parts of the terrain are visible, scale is fairly uniform throughout, and complex methods are not needed to make simple maps. Three-dimensional effect of terrain is easily seen with stereoscopes, which is of exceptional value for interpretation.

Oblique photographs

Oblique photographs have one factor in common; the camera is at a predetermined, definite angle to the ground. Division into low and high oblique photographs refers only to this angle not to the altitude of the camera.

Low oblique photographs

The low oblique photograph can be defined best as an angled camera shot that does not include the horizon. The angle gives greater ground coverage. Advantage is taken of this for cheaper mapping. The photographs are later "restituted" by rephotography in the darkroom and made into verticals if their angles were low. Higher angles require special mapping techniques. We can use obliques to bring maps up-to-date in small areas but the methods are tedious for large ones.

Our use of this class of photograph is limited to the large-scale casual, single photograph taken at low altitude, for public education, reports, demonstrations and similar needs. The viewpoint is normal. It explains matters such as small-tract developments and recreational areas in a way no other may.

High oblique photographs

The high oblique photograph includes the horizon. The perspective is natural. Reference to objects in the photograph is readily understandable because of its pictorial nature, which resembles the normal view from a mountain or airplane. It is therefore, very good for displays, presentation of entire watersheds or other problems, especially with the public, where quick recognition and reference are desirable. The limitations of high oblique photography come in mountainous or hilly areas as slopes facing away from the camera are unseen or minimized.

Reconnaissance mapping combines three cameras--two high oblique and one vertical--for a horizon-to-horizon photo coverage which is interpreted by special drafting techniques into relatively inexpensive maps. The vast glaciated plateau of northern Canada with its flat, level terrain is ideally suited to this. As a Bureau we may have use for such mapping in similar territories in Alaska.

Summary

The Bureau confines most of its use to the vertical photograph because of its advantages in requiring little equipment to record its information in a usable form. This is related in turn to its relatively uniform scale, the map-like presentation of information, and its general availability and consequent cheapness.

Obliques are more specialized. The specialization is advantageous in that the perspective may approach a normal viewpoint, thus interpretation is easy for the average person.

All types demand infinitely greater integration into our Bureau programs as they will perform services that cannot be achieved by other means.

Films

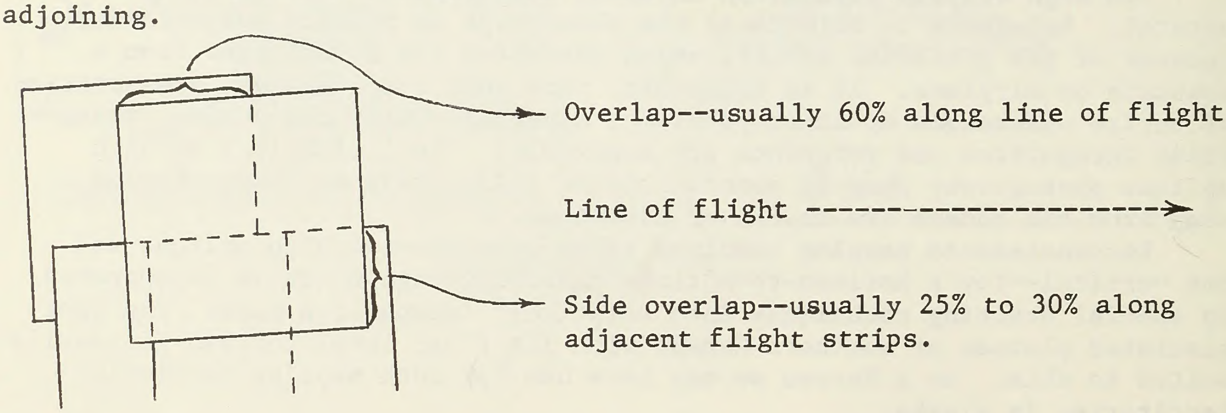
The film used for most aerial photography is one that renders the gray tones of the photograph in the proper relationship to relative brightness of actual colors. This type of film is termed panchromatic. For all but the most specialized requirements it is the cheapest and most useful.

Color film is used in specialized interpretation work. Difference in geological strata is sometimes detectable in only one way--by color photography. Infrared film, a specialized type of color film is also used. The Bureau may find a definite need for aerial color-photography. Minerals, for example, can be detected by different colors of rock strata or vegetation.

Infrared film depends on invisible infrared rays (not dispersed by atmospheric haze) to produce black-and-white print with detail in the distance. There is a change in color relationships due to difference between reflected visible light and reflected infrared rays. This peculiarity is used in mixed-timber stand aerial photography to differentiate softwoods from hardwoods. Infrared film with appropriate filters can give a clear high-oblique photograph covering an entire watershed.

Photography

Aerial photographs are taken on clear days when the sun is high enough to avoid distractingly heavy ground shadows. The pilot flies at an equal altitude throughout the target area. Each flight must parallel those adjoining.



The ideal flight pattern is difficult. Sidewinds require flight corrections. The camera may be at an angle to the flight; then overlap and side overlap will grow inadequate with "crab." If the pilot fails to correct for the wind he will "drift" off the line of flight. Both "crab" and "drift" may require rephotography. Flights are planned along the direction of prevailing winds to minimize this. See Figure 2 for flight patterns.

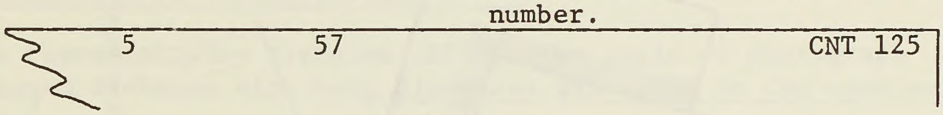
Photographs

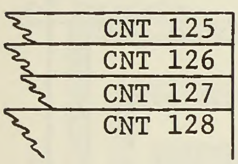
Fiducial Mark

The center of a photograph is sometimes identified by a tiny "x." More often you must determine the center of the photograph from "fiducial" or "collimating" marks on the margin, which cross at the center when extended.

Photographs have individual identification. Each photograph is numbered consecutively as it is taken. Usually the date is included.

Month Year Contract flight and photograph number.

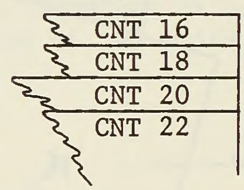




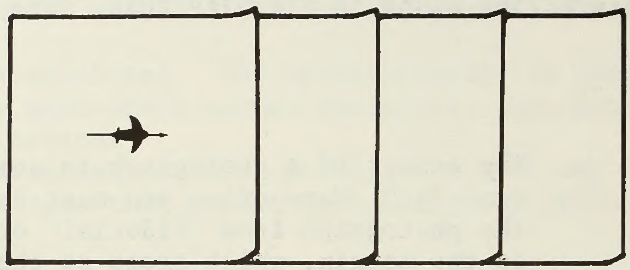
These photograph numbers indicate "full" coverage.

Every exposure is necessary for stereoscope work.

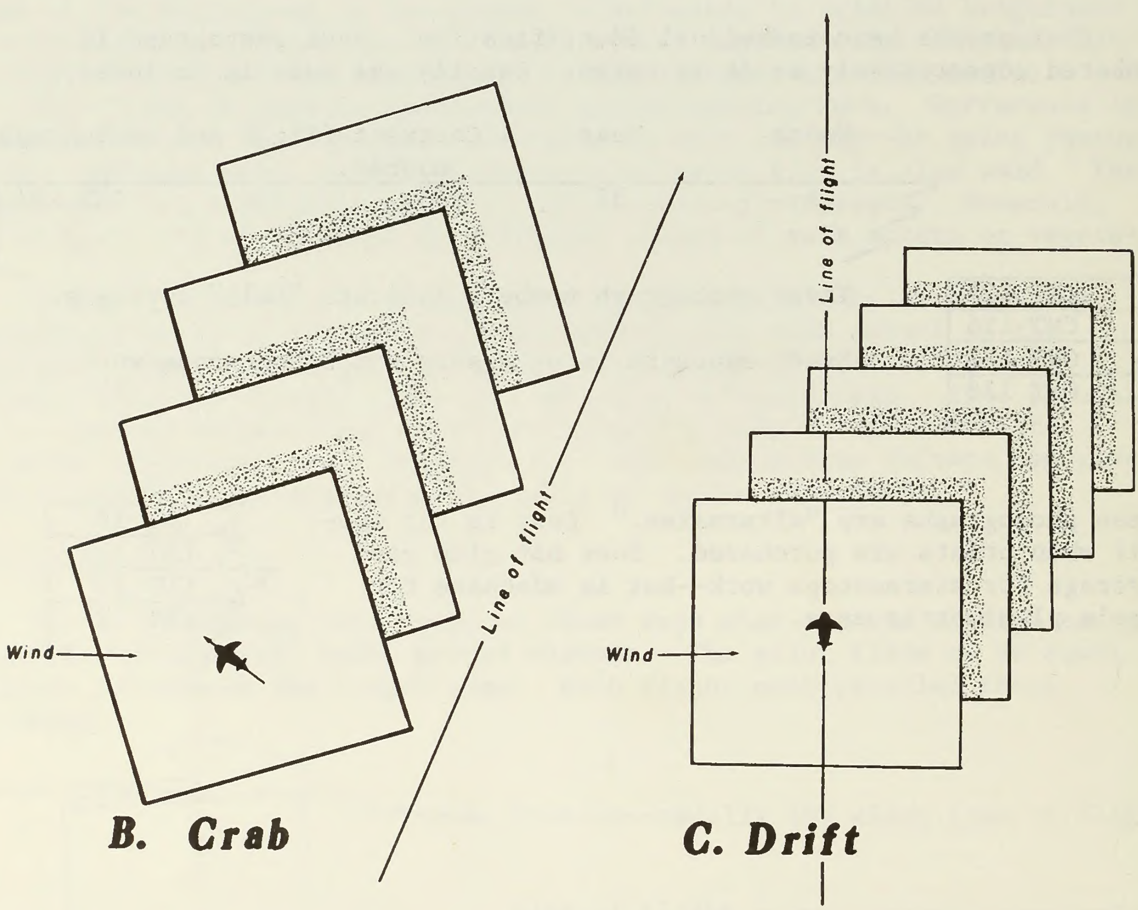
These photographs are "alternates." Cost is cut one-half when prints are purchased. Does not give good coverage for stereoscope work--but is adequate for simple planimetric maps.



Index flight paths.



A. Desired pattern of flight.



B. Crab

C. Drift

Figure -- 2

Scale

The scale of an aerial photograph is a vital piece of knowledge for your work. It is the ratio of the distance on the photograph to its actual distance on the ground. This ratio of photo distance:ground distance (PD:GD) is the scale. It is expressed usually in three ways:

A. Descriptive scale

The descriptive scale is in common use. It is a statement of ratio in familiar terms, such as "1/2 inch = 1 mile." It is awkward, however, because two different units of distance are used, one for the ground and one for the photograph. Inches on the photograph are related to miles on the ground.

B. Graphic scale

The graphic scale permits direct measurement on the photograph in a convenient unit (miles, yards, feet). There is no calculation in its use; hence it is rapid and easily used.

C. Representative fraction scale or RF

The representative fraction (RF) is the ratio of photograph distance to ground distance with both distances expressed in the same unit of measure.

$$\text{Scale} = \frac{\text{photo distance}}{\text{ground distance}} \text{ or } \frac{PD}{GD} \text{ or } PD:GD$$

This is the basic statement of scale for all map and photograph work. It is best suited for calculations. Example of an RF is 1:63,360, which is the same as stating "1 inch = 1 mile" (63,360 inches). Thus the RF is really the familiar descriptive scale with the confusion of two units of measure removed.

Scale in the photograph (Figure 3)

Scale in an aerial photograph is determined by two factors at the moment it is snapped:

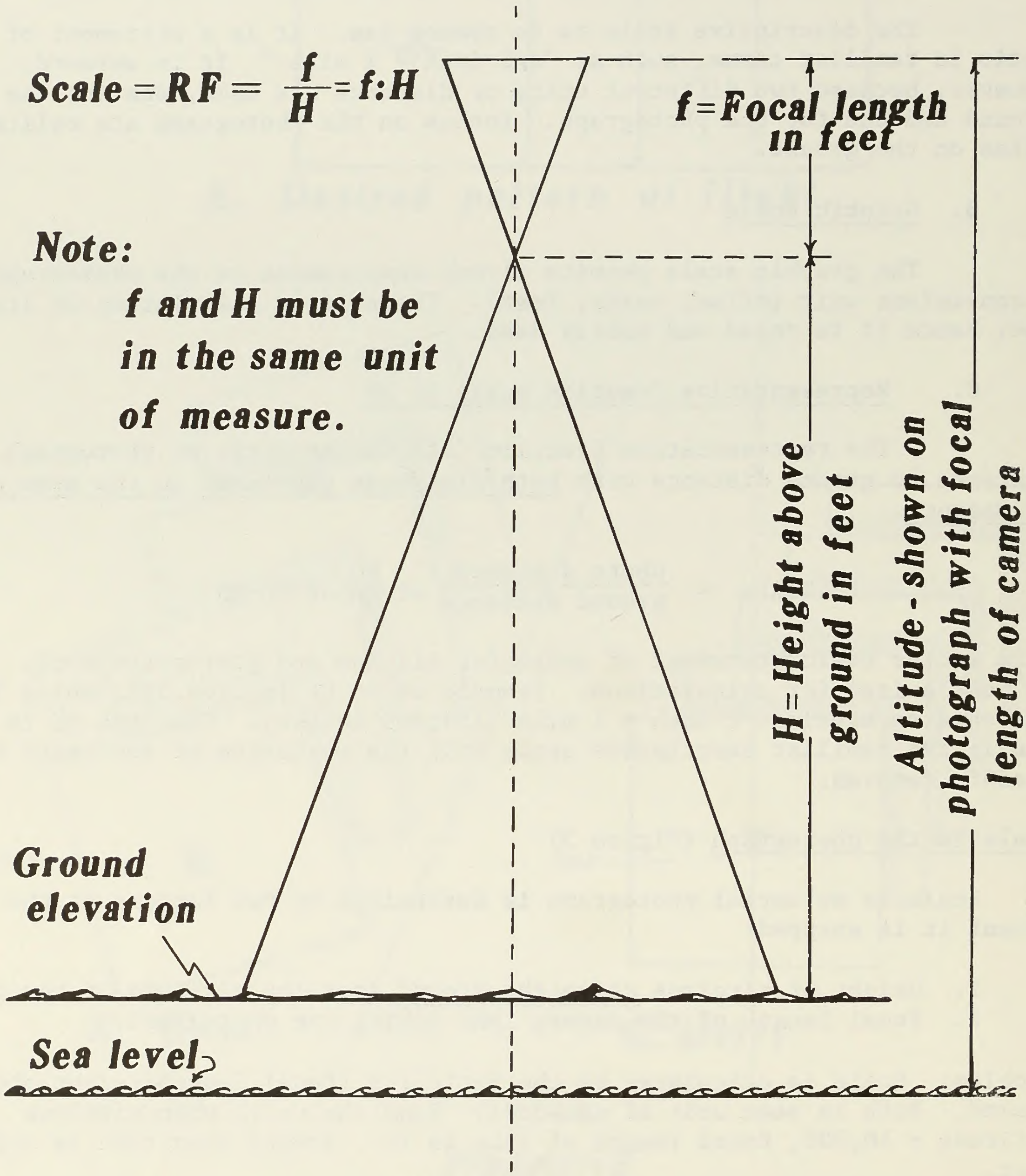
1. Height of airplane above the ground (not the altitude of the plane).
2. Focal length of the camera lens taking the photograph.

Problem: Scale is calculated by the ratio f:H (focal length:Height above-ground. Both in same unit of measure). Find the scale when airplane altitude = 10,000, focal length of lens is 12", ground elevation is 3,000 feet.

Solution: Subtract 3,000' from altitude = 7,000', or H. f = 12 inches or 1 foot. Scale = f:H, or 1:7,000.

Determination of photo scale from lens focal length and altitude.

The scale of photographs is usually given as a representative fraction (RF) and written on one line (1:5,000). If a vertical photograph contains the altitude and focal length of the camera, the scale is obtained as shown below.



Figure··· 3

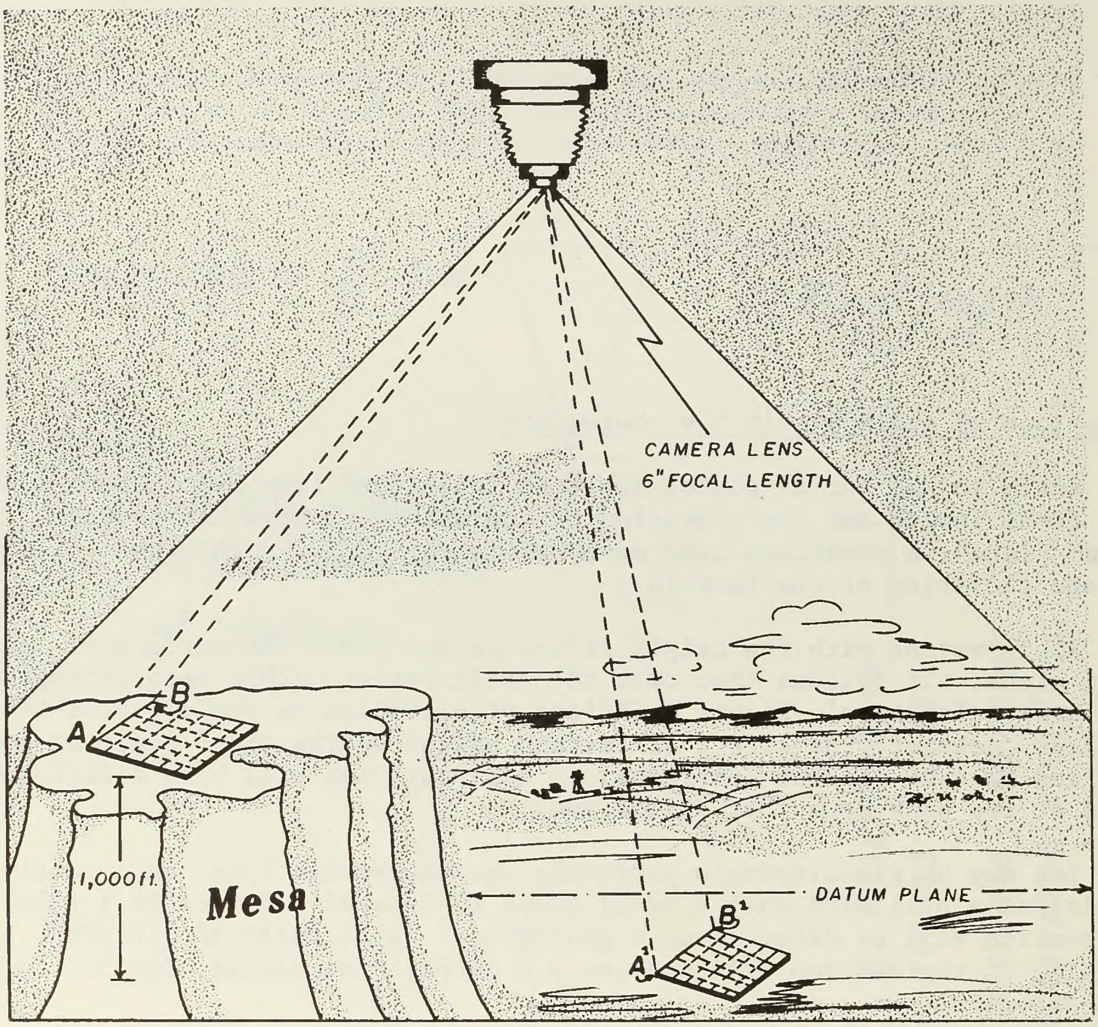
Variations of scale within the photograph

Scale in the aerial photograph then is derived from two factors--the lens focal length and the elevation of the airplane above the ground. "Datum plane" is sometimes used as a reference; it is roughly that of the average elevation of the terrain.

Scale varies with the height of the camera above the surface of the datum plane. It follows then that the scale varies within each photograph with every elevation! Figure 4 (Effect of elevation on scale) shows this problem. However, the effect of terrain height on the photo scale is not confined to such violent contrasts. A tall building will have a different scale at its base from that of its roof.

You may be classifying a perfectly square section lying on a gently sloping side hill with only a small grade (a rise of 300 feet in 1 mile). The section will be deformed on a photograph. At a scale of 1:21,000, the low side of the section will measure 3.0 inches; the higher side 3.1 inches--a 3% error!

Effect of elevation on scale.



$$\text{Scale} = \frac{\text{FOCAL LENGTH IN FEET}}{\text{ALTITUDE IN FEET}}$$

Scale on mesa top

$$\frac{.5'}{9{,}000} = \frac{1}{18{,}000}$$

1 mile = 3.5"

Scale on valley floor

$$\frac{.5'}{10{,}000} = \frac{1}{20{,}000}$$

1 mile = 3.2"

Figure -- 4

Determining the scale of a photograph from a map

A large-scale map (1:25,000 or 1:50,000 USGS) is good for calculating the scale of a photograph. The same points must be recognizable on both map and photograph. Pick two pairs of points, each point should be located as far distant from the other as possible; a line connecting each pair should pass close to the center of the photograph, forming an "x" (not illustrated).

The calculation of Figure 5 is typical for one pair of points. Here "A" and "B" were recognizable on both map and aerial photograph. First determine the actual ground distance between "A" and "B". The distance between them on the map is 1.2 inches. Map scale is 1:50,000. Therefore, ground distance is 1.2" x 50,000 = 60,000 inches from "A" to "B". Now to determine the photograph scale as the ratio of photo distance to ground distance (PD:GD). PD is 2.5" on the photograph (by measurement) and GD is 60,000" (calculated from the map). The ratio, therefore, is 2.5":60,000". Divide both parts of the ratio by 2.5 which gives the answer: Photograph scale = 1:24,000. The pairs give two scales, which are averaged.

Determining the scale of the photograph in the field

The scale of a photograph is easily determined in the field. Two pairs of points are located on the photograph along roads or routes that can be measured easily. Example: Assume the distance along two roads averaged 1.7 miles and the distance measured on the photograph averaged 2.3 inches. Find the photograph scale.

Converting miles to inches gives all measurements in a common unit (1.7 x 5280 x 12" = 107,712"). The scale PD:GD 2.3":107,712" = 1:46,831, or, in round numbers, 1:47,000.

Determining the scale of the photograph by comparison

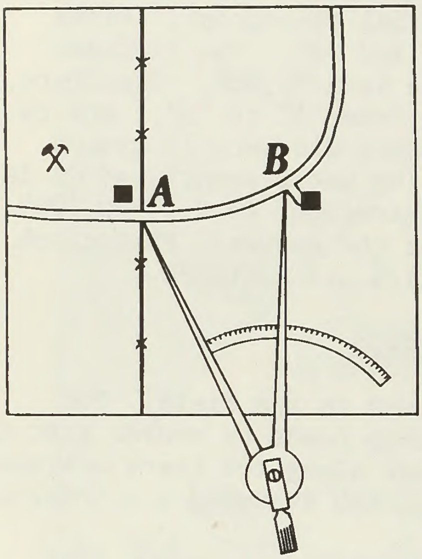
Sometimes the photograph will reveal square sections. A quick measurement can give the inches per section line on the photograph, perhaps 3" = 1 mile (3" = 63,360"), which can be resolved by inspection into the familiar 1:21,000.

Use of scale

Bureau personnel use photograph scale extensively for location of legal subdivisions ("sectionizing"). One major use is seldom made--determination of exact size of the objects on the ground. A special scale, easily purchased and inexpensive, used by photo-interpreters reads in thousandths of a foot. Assume a dam shows on a photograph with RF 1:21,000. The photo-interpreter's scale is in feet instead of inches; therefore, a measure of the dam as .015 feet is calculated as .015 x 21,000 (PD:GD) = 315 feet long for the dam. Saves walking!

Determination of photo scale.

Photo-scale unknown



Distance AB = 2.5" on photo

Distance AB = 1.2" on map

Problem:-

Determine scale of photograph.

Scale = ratio of map distance to ground distance.

Therefore:

1.2" x 50,000 = 60,000" ground distance between AB.

Map-scale 1:50,000

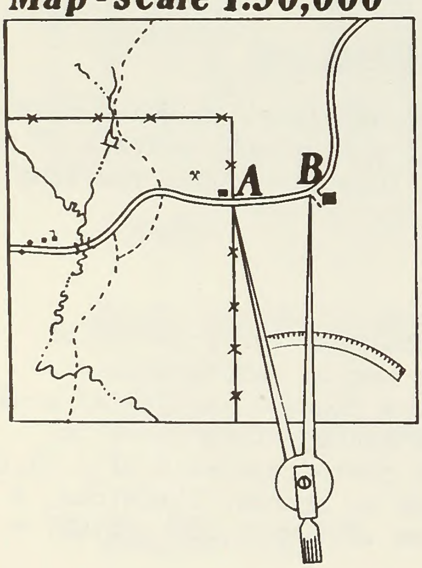


Photo scale

$$\frac{\text{photo distance}}{\text{ground distance}} = \frac{2.5''}{60,000}$$

ANSWER:

$$\text{Photo Scale} = \frac{1}{24,000}$$

Figure··· 5

Photograph indexes

Possession of aerial photograph coverage means little without an efficient way to catalogue that coverage. The aerial photo-index is the answer. This has several forms, all of which aim at one objective--identifying the aerial photograph with the terrain.

Contract flights usually offer a photo-index at extra cost. The photographs for an area are placed in their relative positions with individual identity accented; a large photograph is then made of this group. If there are prominent terrain features evident, the photo-index can be used for location of desired photos. A measure of control is present; townships can be superimposed on these photo-indexes with fair accuracy. Unfortunately an index of this sort usually is difficult to read and use.

Better indexes may be prepared by Bureau offices on a suitable base map. The Army Map Service 1:250,000 series (with township overprint) is good for large photographs. County highway maps, usually on 1/2" = 1 mile (1:138,000 scale) are handy but often lack sufficient detail. The AMS series can be matched for detail between base map and photograph.

First a hole is cut in lightweight cardboard to the overall photograph size relative to the scale of the base map. This template will show the exact coverage on the individual photograph. The template is moved around on the base map until terrain features included by the template match those of the photograph. This identification of photograph to the base is easy. The area of the photo is outlined and the photograph number placed within the outline.

A typical calculation for template size is covered in Figure 6. The photographs are the common 9" x 9", RF 1:21,000. The base map is 1:100,000 scale.

1. First determine distance of the photo dimensions represented on the ground: 9" x 21,000 = 189,000" (photo edge) x (photo scale).

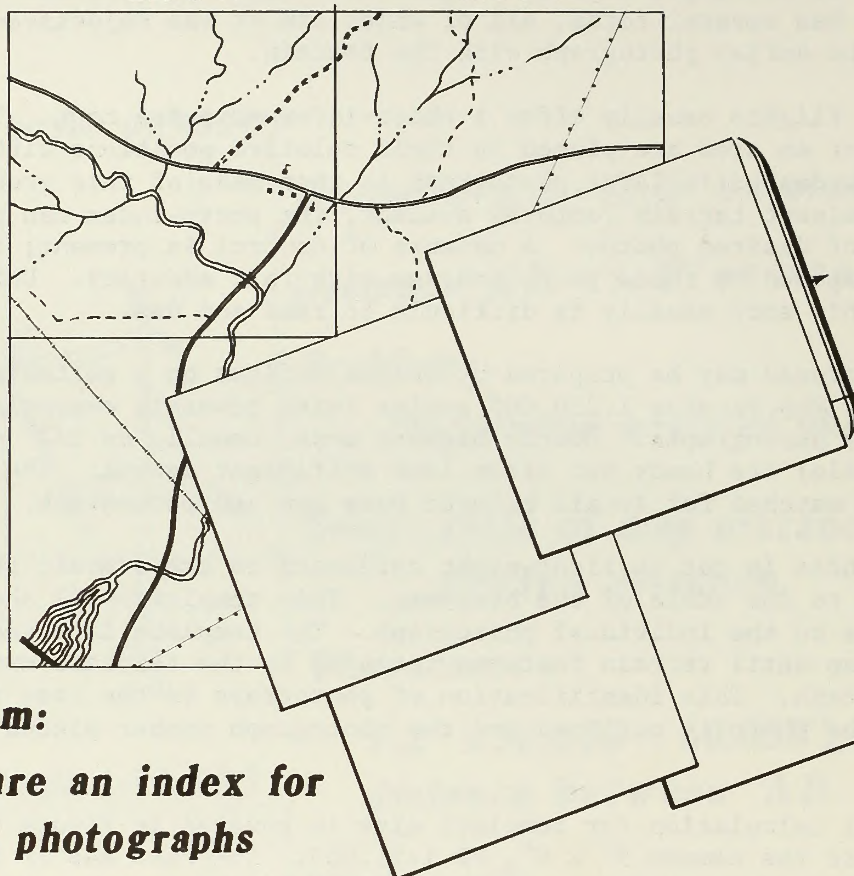
2. Each dimension of the photograph is 189,000" on the ground.

3. Convert this distance to base map scale of 1:100,000 by setting up the proportion 1:100,000 :: X:189,000"; then 100,000X = 189,000" or X = 1.89". Accordingly, the template size is 1.89" x 1.89".

A quicker system is that of inking the photograph number only, on the base map at the approximate location of the photograph center. This saves time in the initial preparation of an index. This base can be increased in its effectiveness later by indicating each photo coverage by templates.

Photo-index maps are genuine time and money-savers.

Aerial photograph index.



Problem:

Prepare an index for aerial photographs 9" x 9", scale 1:21,000 for a base map, scale 1:100,000

Template size:

1. **Ratio of photo distance to ground distance = 1:21,000**
   Photo = 9"   9" x 21,000 = 189,000"
2. **Ground distance 189,000"   Map 1:100,000**
   therefore: $\frac{189,000''}{100,000}$ = 1.89" x 1.89" Template size.

Template is then oriented to the ground features of the base map.

Figure···6

Graphic scale

A graphic scale is included in most printed maps. Even maps of nonuniform scale, such as "The World" on a mercator projection, will have a series of graphic scales despite the clumsiness of this arrangement. There is one reason for this common acceptance of the graphic scale--it gives measurements directly.

You may find times when a photograph will be in constant use, as in small tract areas next to a town. Inquiries from the public on the tracts may require quick answers in terms of distance, and many measurements in approximate terms. It will pay to construct a graphic scale for this aerial photograph if the scale is uniform throughout.

To illustrate the construction of a graphic scale for a photograph, assume the problem is an urban development requiring many measurements. You wish to construct a graphic scale divided into hundereds of feet and capable of measuring a total distance of 5,000 feet. See Figure 7.

1. Calculate that distance on the photograph which is in correct relation to ground distance of 5,000 feet.

a. Scale of the photograph is 1:20,000 (Photo Distance-Ground Distance).

b. Ground distance is 5,000 feet or 60,000 inches.

c. The ratio is set up comparable to the photo RF. Unknown photograph distance to the known ground distance is X":60,000". Then, 1:20,000 :: X":60,000". Solving: 20,000X" = 60,000", X = 3" as representing 5,000 feet on the photograph.

2. Lay out 3 inches on a cardboard edge.

3. A simple way to divide this 3" line into five, or any number of divisions, is shown in Figure 7.

a. Obvious divisions of the dividing scale or ruler are chosen for convenience (5 inches for fifths, 6 inches for sixths, etc.). The dividing scale is laid at a convenient angle to the graphic scale with the "Os" for both scales coinciding.

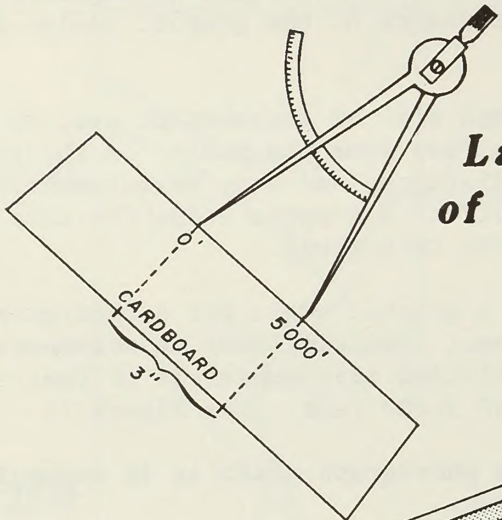
b. The end of the fifth division of the dividing scale is connected by penciled line (baseline) to the end (5,000') of the graphic scale. Then each equal division of the graphic scale (or 1,,000 ft.) is determined at each inch by a line drawn parallel to the first baseline.

4. The finer divisions in this problem, 100 foot intervals, are determined in the same way.

Graphic scales for aerial photographs.

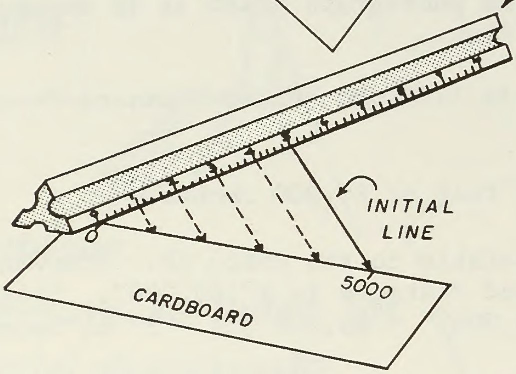
Problem- Construction of a graphic scale on photo RF 1:20,000 . Scale 5000 feet in length.

Lay off 3 inches on a strip of cardboard.



Place ruler or scale at a convenient angle.

Any five equal divisions divides strip into fifths, when construction lines parallel initial line.



Smaller intervals (100 feet) are done in the same manner.

A scale with 10th. markings is best to use.

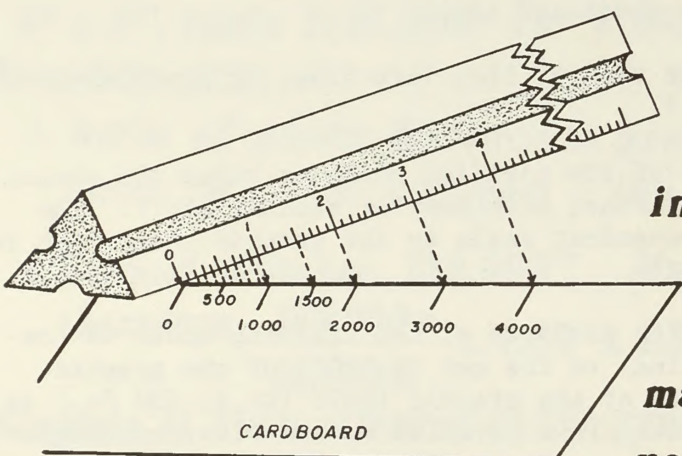


Figure ···7

Distortion

Distortion in the photograph arises from the differing scales and displacements within its edges. Some distortions are minor problems; others require expensive investment in man-hours for full correction. Normally, many of these difficulties can be resolved satisfactorily by the Bureau personnel. This means the various types of distortions must be evaluated and their remedies checked for effectiveness against our present capabilities.

Minor distortion

Darkroom processing accounts for some minor distortion in photographs. The wet paper print may stretch in one direction and shrink in another dimension upon drying. Such errors are lessened by use of double-weight paper of good quality. Single-weight paper is used in mosaics where stretching sometimes is done purposely for a match of detail.

Distortion from the camera lens may be present. If the photographs are enlarged, the enlarging may introduce further errors. This difficulty is avoided by your confining the work to the center of the photograph. Use more photographs if necessary.

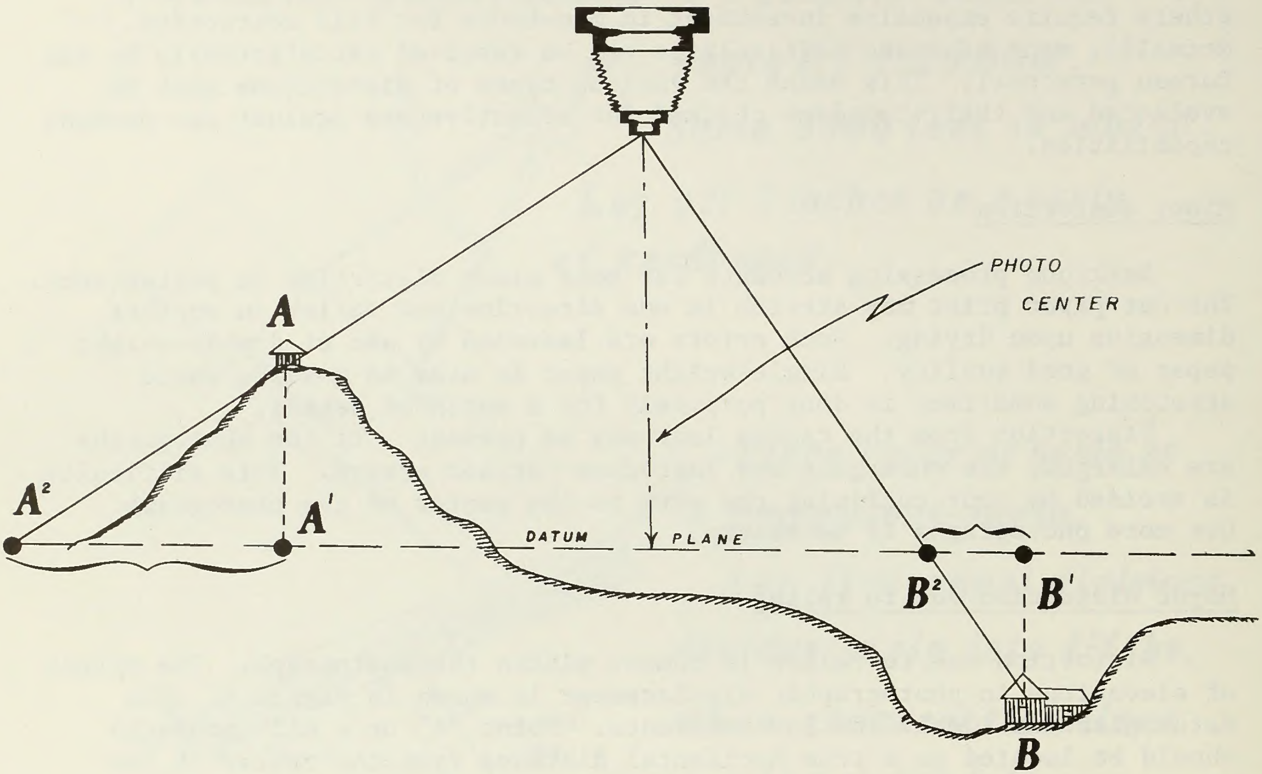
Major distortion due to relief

Distortion due to relief is common within the photograph. The effect of elevations in photographic displacement is shown in Figure 8. The datum plane is identified for reference. Point "A" on a hill properly should be located on a true horizontal distance from the center of the photograph at "A1," but is displaced outward in the photograph to "A2". Point "B" is below the datum plane. Its correct location on the datum plane is displaced toward the photograph center, in this case to "B2". A matter for emphasis is that in both situations the displacement of a point inward or outward is on a straight line from the center of the photograph.

Displacement of a point then is caused by the effect of relief. No matter to what degree points are displaced they move inward or outward on a line radiating from the center. A compass bearing from the center to the object point will not change with displacement. A hilltop, in the several photographs surrounding it, is displaced outward on a line from each center. Assume this center of each photograph is located correctly in its relative ground position. Every line bearing on the hilltop from each center is on a true bearing. The point where the lines intersect represents the true horizontal location of the hilltop.

Intersecting rays from the centers of overlapping photographs are plotted to locate points in true horizontal position and thereby eliminate displacement due to relief. This is the basis of the "radial-line" and "slotted-templet" method of map preparation. We can adapt this technique to locate single objects, such as a new radar site on a hill.

Distortion due to relief.



A' to A² = Distance of displacement away from center of photograph.

B' to B² = Distance of displacement towards center of photograph.

A' and B' = Corrected positions.

A² and B² = Displaced positions on photograph.

Figure···8

In Figure 9 we see the distortion of a square section because of rugged terrain. The center of the section and the picture coincide. Two corners lie on the datum plane, whereas, NW is above and NE is below it. NW will displace outward, radially, from the center and NE will displace inward, radially, toward the center because it is located in a deep canyon. The square section is illustrated with solid lines; dotted lines show the deformation of the section as it is depicted in the photograph.

Distortion due to tilt

Angled photographs have distortion known as "tilt"; it is like that of a low oblique photograph but uncontrolled. Tilt is divided, sometimes, into two parts--tip and tilt--for computing corrections. Tip in a photograph is caused by the airplane climbing or diving at an angle to the ground. At right angles to tip is "tilt" as the airplane banks in flight. We neglect tip and tilt in our calculations because it must be over 3 percent for serious distortion. The Bureau does not use vertical-photograph flights that exceed that amount overall. Thus tip and tilt, or tilt alone, causes distortion in photographs but can be disregarded for our work.

Summary on distortion

We work often in terrain with pronounced relief. The photographs have invaluable information but also have errors which must be recognized and, if necessary, corrected. You can correct many of these errors as you gain experience but for now:

Distortion from camera lens--use the center of photograph.

Distortion from photo-processing--order double-weight stable paper.

Distortion from tip and tilt--order photography of less than 3 percent error.

Distortion from relief--

Terrain affects all aerial photographs. Small corrections may be made by adjustment to known surveys. Radial-line correction with other photographs is effective and definitely within the capabilities of the Bureau field offices. It is explained in Department of the Army publication TM-5-240.

You may estimate the differences in elevation to calculate the correct length of the section line.

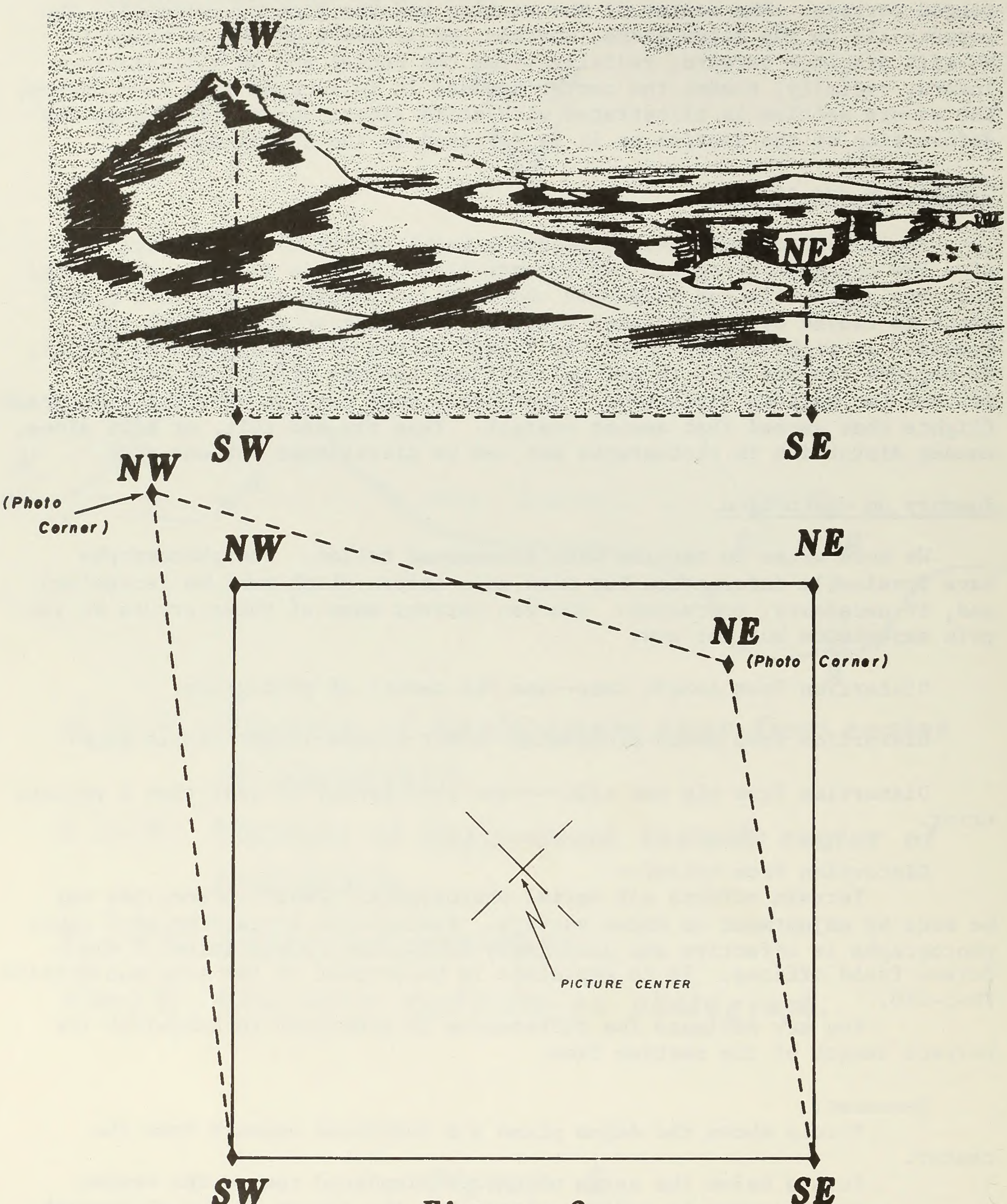
Remember:

Points above the datum plane are displaced outward from the center.

Points below the datum plane are displaced toward the center.

Displacement is radial relative to the center of the photograph.

Distortion due to relief.



Figure··· 9

Interpretation of photographs

Occasionally the terrain features of a photograph "reverse" themselves; that is, the drainages appear as the highest points. Turn the photograph so that its shadows fall toward you. This will force the features into proper location. However, some surveyors make a practice of working part-time with the relief reversed. They keep the streams up above the country in the photograph for ease in drafting drainages!

Direction is important. In northern latitudes the shadows in the photograph fall toward the northwest if taken in the morning and northeast for those taken in the afternoon. North is determined with greater certitude by comparison with a map of the area or orientation by compass. Photo-flights are usually flown in cardinal directions--east-west or north-south--with photo-identification uniformly presented at one end of the photograph--the west or north side. Watch out for odd flights that vary from this or where two differently oriented flights join.

Guides in interpretation (Figure 10 & 11)

The vertical photograph is the most versatile of the aerial photographs. Unfortunately, the relation of the camera to the ground gives an unfamiliar aspect of familiar objects, often in much reduced size. Too, there is an overabundance of detail because of the nonselective nature of the camera lens. Important items may be subordinated. Guides are consciously developed to help us interpret the information in the photograph. These are:

Shape - Shape may identify.

Tone - Photographic tone is the gray shade of an object in the photograph. Texture is a variation of tone, made up of indistinguishable features.

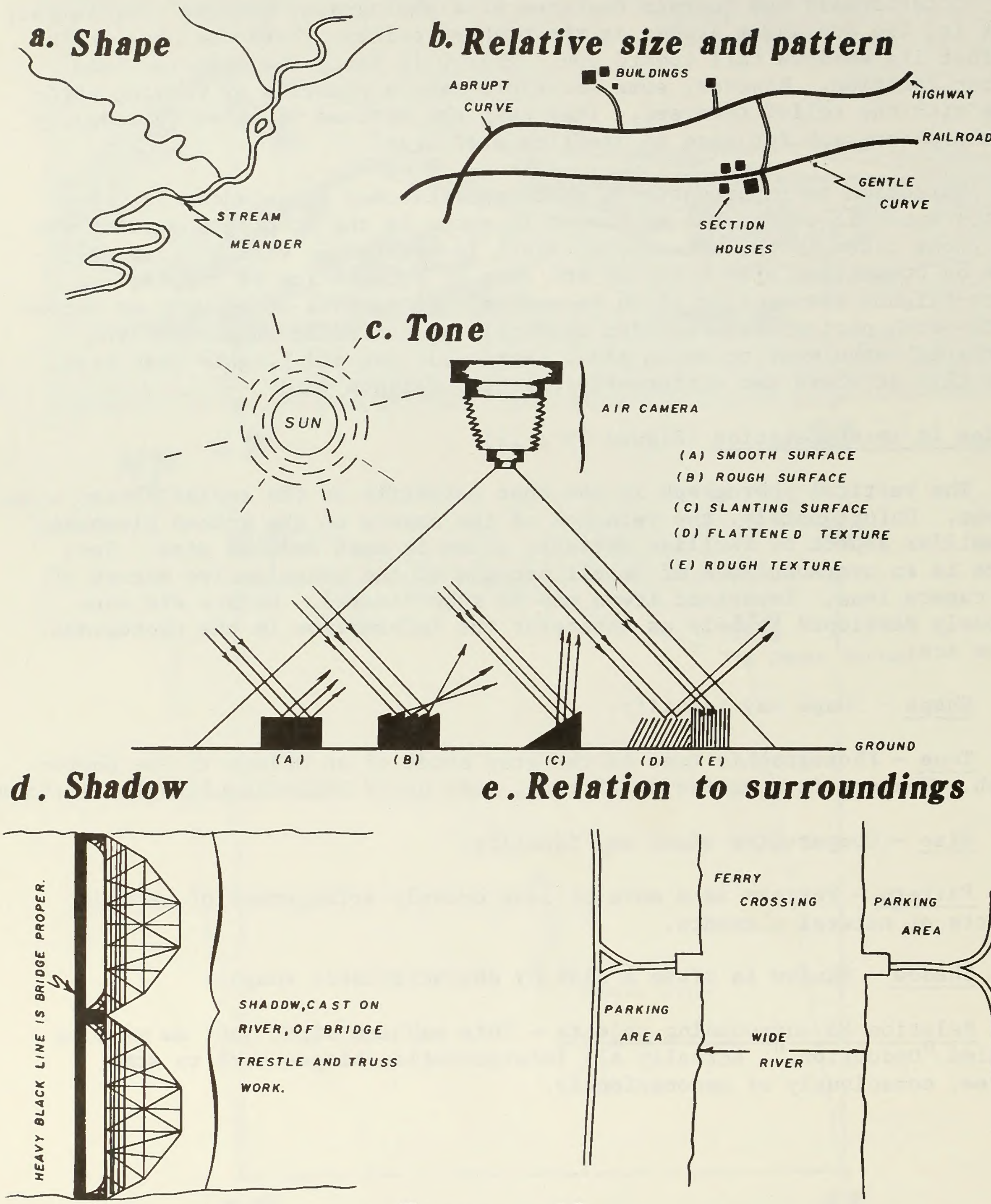
Size - Comparative sizes may identify.

Pattern - Pattern is a more or less orderly arrangement of manmade objects or natural elements.

Shadow - Shadow is often a clue by characteristic shape.

Relation to surrounding objects - This subhead might just as well be labeled "Deduction." Actually all interpretation hinges here to some degree, consciously or unconsciously.

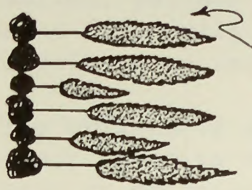
Identification of objects.



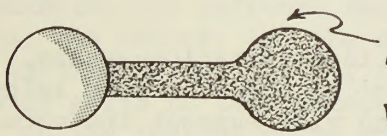
Figure··· 10

Shadow.

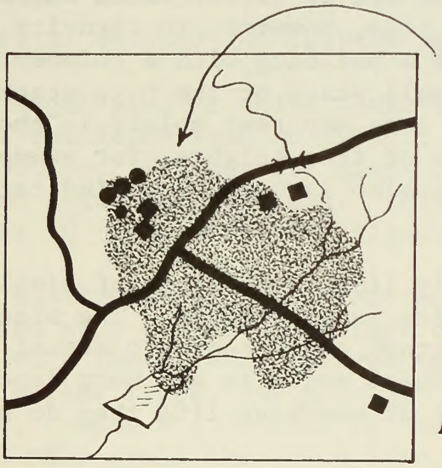
Useful for large objects and large scale photographs.



Shadow identifies object as a wind break of Lombardy Poplar.

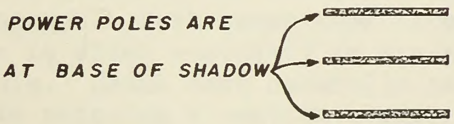


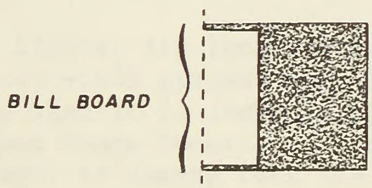
Shadow identifies object as water storage tank.



Watch out for cloud shadows! Cloud shadows give a dark tone that bears no relationship to terrain. However, in flat level country, these shadows may puzzle photo-readers.

Sometimes there are shadows without objects— distinguishable that is!





Figure···11

Shape, shadow and size - Three guides to identification--shape, shadow and size--are closely related. Shape of an object may be inferred from its shadow. The distorted shadowy outline will suggest the normal side view. Shadows are strongly indicative of the nature of the object but are too often lost in uneven terrain and are of little value where the scale of the photograph is small. The one clue, however, to identity of an object may be its shadow. An example is a building with a chimney. The shadow will indicate whether it is a small stack or the huge stack of a cement plant or smelter; the clues in this case may rest solely in the shadow. Shadow will give a good indication of tree heights, for example, when one or two heights are determined, and also is used as an indicator of direction.

Shape and size of an object are closely linked. Objects of similar shape may await identification until the size is determined. The size can be calculated by measurements on the photograph converted into actual size by the factor of the photograph's scale. Shape and size are very important in recognition but are such a constant part of everyday life they do not require emphasis here.

Tone

Photographs render objects as tone of gray. The photographic print has on one extreme the whitish-gray of the paper base and on the other extreme dense, grayed blacks without detail. From picture to picture, the tone varies, perhaps because of darkroom processing or the fact that different films will render the same object variously. Filters, exposures--all contribute to varying the tone of an object.

The brightness of an object will be interpreted as a gray tone on the photograph relative to those of other objects. Color determines the lightness or darkness of a tone. However, the texture of the surface, independent of color, affects the one also because the light that hits is reflected or absorbed to varying degrees. Coarse-textured light surfaces, for example, are darkened because of the texture. The position of the camera, the object, and the sun also have a profound influence on the tone. Tone may be the outstanding factor for a specific recognition. More space has been given to tone because of this, especially since the concept of tone, unlike that of shape and size, as guides to recognition, is not a familiar part of our everyday life.

Effect of surface and texture on tone (Figures 10 and 12)

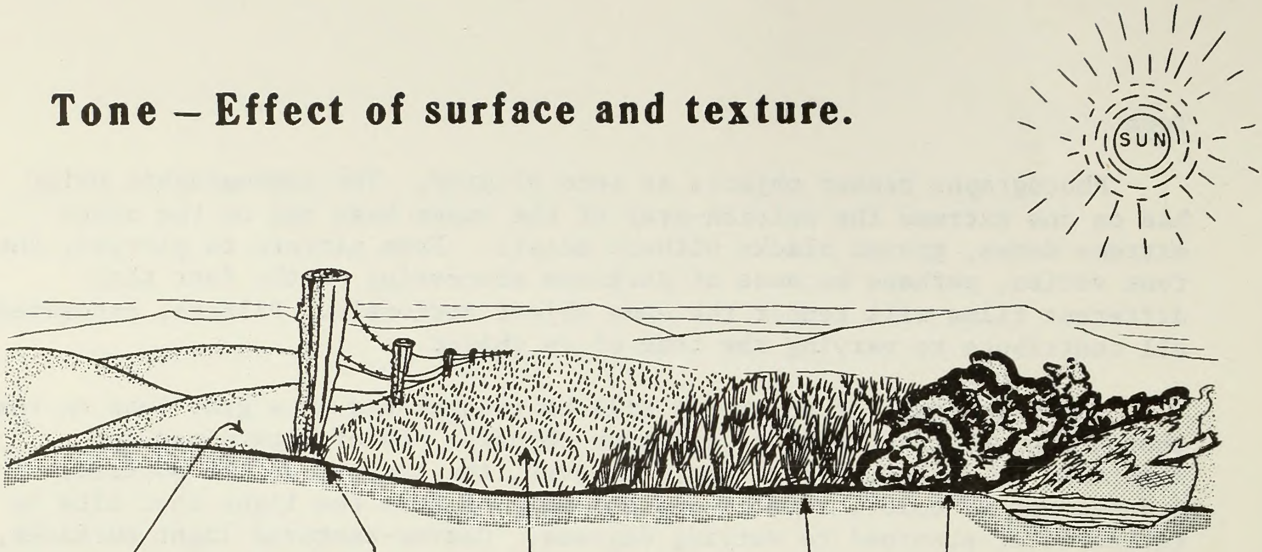
Light-gray or white tones in a photograph come from a large amount of light reflected from an object. A smooth surface reflects well despite a dark color. Witness the glare off a highly polished hood of a black sedan as you drive into the sun. This same situation prevails on the ground. Figure 10 (general plate) illustrates degrees of reflection under "tone."

Relations of tone to surface are shown in Figure 12. Heavy grazing removes many of the tiny traps of sunlight--grass blades. Reflection is high with the grasses removed so the tones grow light. Ungrazed grasses give darker tones. As grazing is seldom the same on both sides of the fence, fences are located by this difference in tone alone. Sometimes stock will trail the fence line, removing all vegetation and making the surface very smooth. The result is a thread of white line paralleling the fence.

Taller grasses trap more light and reflect little toward the camera. Meadows with greater densities of grass will be darker accordingly than surrounding grassland. Shrubs and trees reflect little light and usually are very dark. This tone will vary with individual species.

In general, the smoother the surface the lighter its tone in the photograph. Dark tones come from rough textures--tall grasses and shrubs. Color is often secondary in its effect on tone when it is combined with texture. Check most carefully in puzzling areas where location is important (as in pricking a section corner on a photograph) to assure that the effects of texture on tone is evaluated properly.

Tone – Effect of surface and texture.



Figure···*12*

Effect of color on tone (Figure 13)

Color has the strongest effect on tone. Darker colors give darker tones. The combination of color and surface texture, however, will cause tones to vary to the extent that a second look at the photograph and the general situation is mandatory.

Figure 13 illustrates some puzzlers in that (depending on relationship of sun and camera--Figure 14) the color and texture may reverse our normal assumption. An asphalt highway is dark and smooth. If it should join a light-colored concrete strip, it will be darker in tone relation to the cement. However, the same asphalt road may be lighter gray tone than a railroad track with its ballast the identical color of the concrete. Why? At the crossing the dominant factor is texture; the light-colored ballast is rough and coarse and is depicted as darker. Different lighting at this spot might easily alter these tonal relationships, however.

The fill next to the highway is nearly as smooth as the highway. Color is now dominant over texture. The light-colored subsoil of the fill will photograph lighter than the dark asphalt this time, as we would expect. Watch out, though, for texture; it may upset the obvious answer. Keep in mind the reflecting power of a smooth, dark object and light-colored coarse-textured object.

Tone - Effect of color.

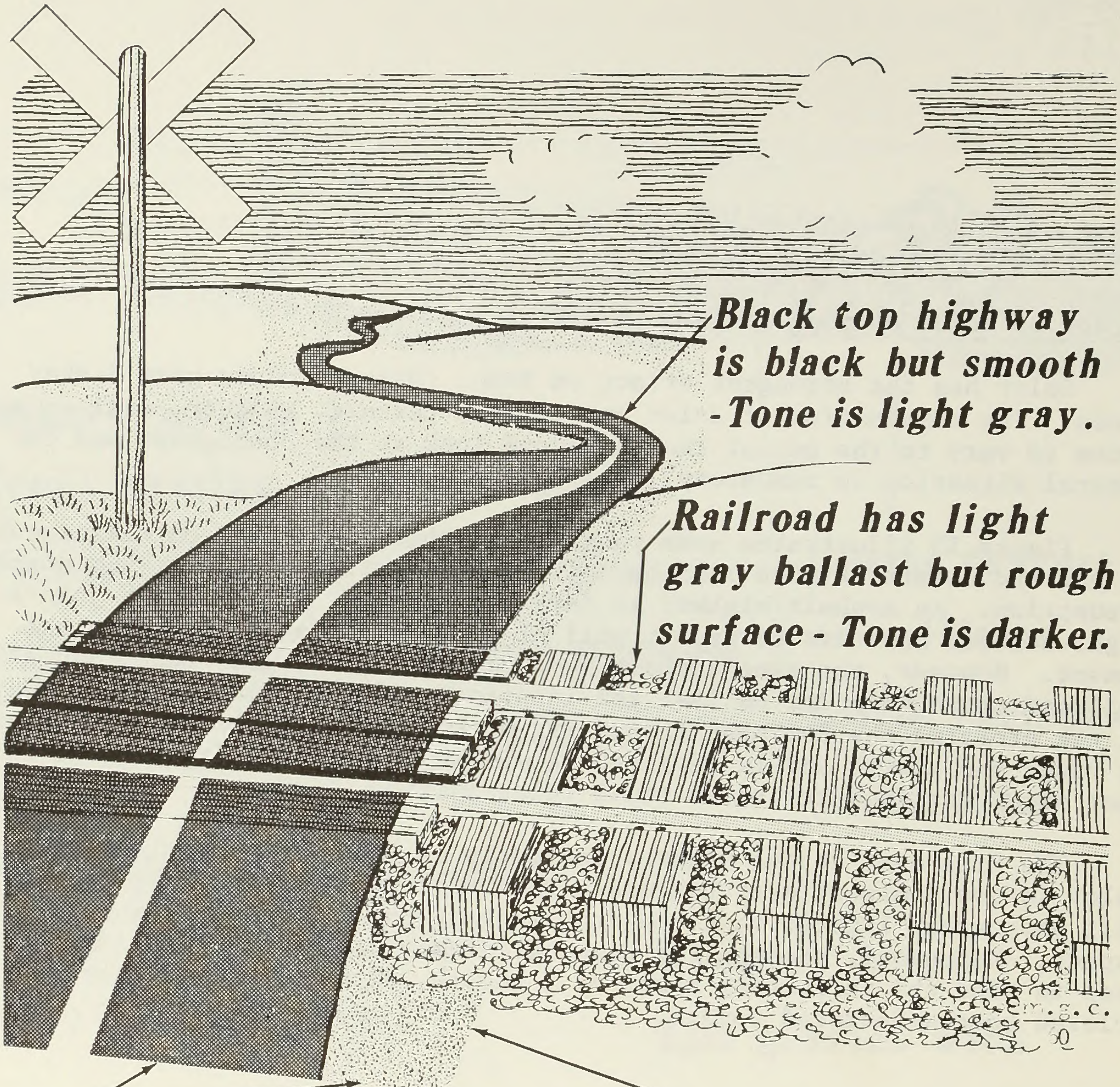


Figure 13

Effect of relation of sun to the camera

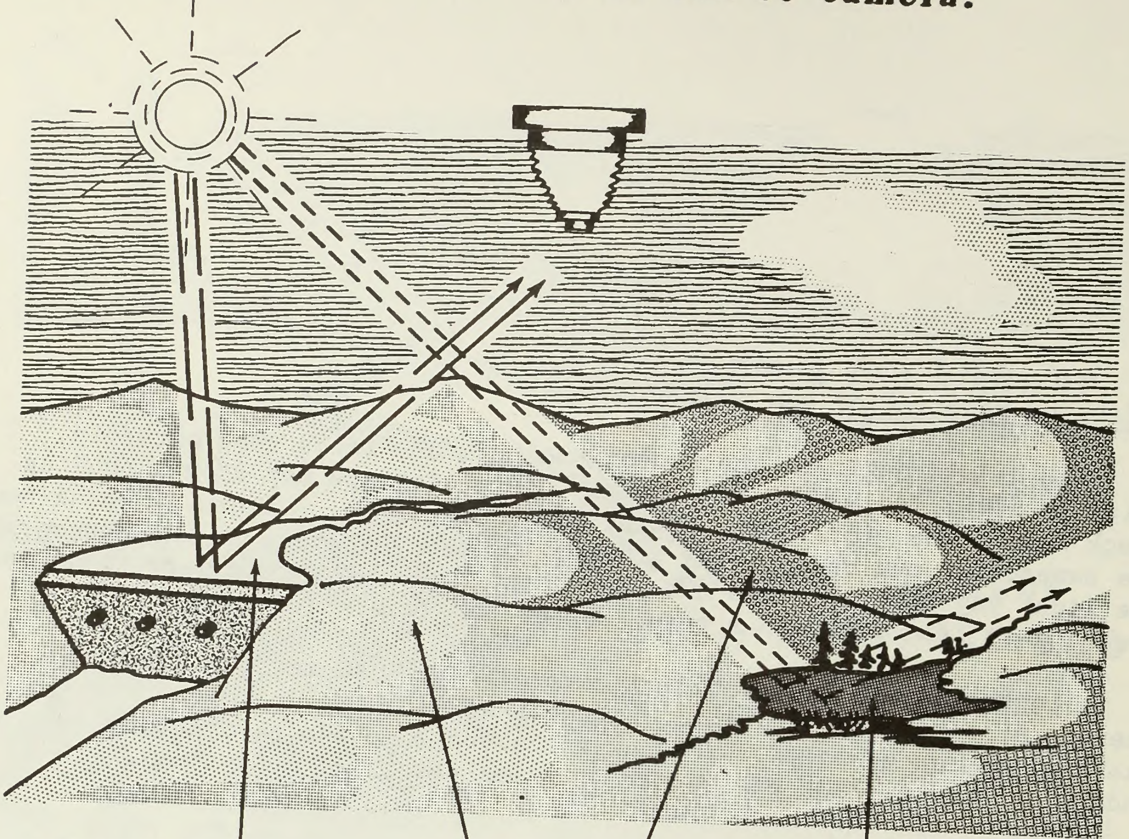
The relationship of the sun to the camera affects tone markedly. Water is level and a good reflector. One photograph may show a pond as black and in the overlapping photograph it is white. Figure 14 shows how the same color and surface may give very different tones in the photograph. The light may bounce toward the camera and render the tone very light, or bounce away from it, with a resultant darker tone.

Slopes in full sunlight will have different angles which result in uneven reflection of sunlight. Ridges that lie on a north-south axis, for example, may show appreciable changes in tones on the same slope in morning and in afternoon light and yet at both periods be in full sunlight.

Texture--a division of tone

Texture as used in the photographic print sense must not be confused with texture of the surface; yet it is a part of that same surface. Actually a photograph tone may differ from an adjoining tone not in gray shades but instead the texture may be "velvety" on one and "pebbly" on the other. This texture comes from tiny patterns and shadows too minute to show up individually on the photograph. The indistinguishable features combine into typical patterns of texture that sometimes give our best identification of vegetation.

Tone— Effect of relation of sun to camera.



Sun rays bounce into camera- water is white tone.

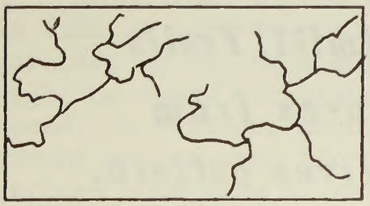
Sun rays bounce away from camera- water is dark tone.

Ground tones are affected similarly - but to a lesser degree.

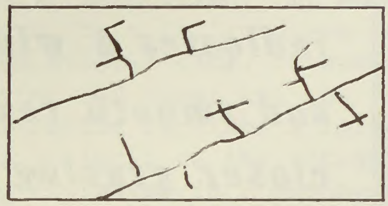
Figure···14

Patterns indicate relationships through repetition or arrangement of objects or form. The relationship may be the typical patterns imposed on a streambed by geology, for example:

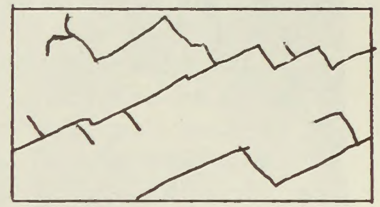
Dendritic (Homogeneous or flat-lying sedimentary rock)



Trellis (tilted or folded sedimentary rocks)



Rectangular (well-developed joints and faults)



The relationship may be typical patterns of culture as in the cloverleaf of the major highways, the symmetry of oil tanks surrounded by circling dikes (Figure 15), or cultivated fields.

Every activity of man and structure in nature falls into typical patterns and arrangements. The major indications of soils and their underlying materials are revealed by gully types and in the pattern of the drainages. Blowing sands and sandy soils have their typical pattern in a photograph, such as the barchans of Figure 15; saline soils in greasewood flats are quickly mapped from the usual pattern of the vegetation growth.

Patterns recur constantly. Where recurrence is marked, entire classification systems are founded on pattern. Soils in highway and airport construction in the United States, for example, have been related almost exclusively to vegetation and drainage patterns. Commercial gravel, in a county composed of noncommercial gravels, had a 90 percent success for location of highway material when it was revealed by interpreting vegetative and stream patterns.

Streets, farms, irrigation systems, mining, dredging, each activity has a typical pattern which can be identified. Bureau personnel, from the wide experience and background gained from the nature of their work, should make an outstanding group in interpretation by bringing economic, agricultural, mineral, urban development, and the like, into constant application.

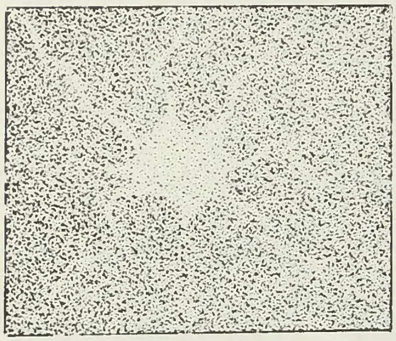
Caution should be used when relying on pattern alone. Do not depend too much on any one factor. Patterns are only as good as the intelligence, experience and imagination of the photo-interpreter.

Patterns are of utmost importance in understanding photographs. Perhaps they should be considered the base for all interpretation.

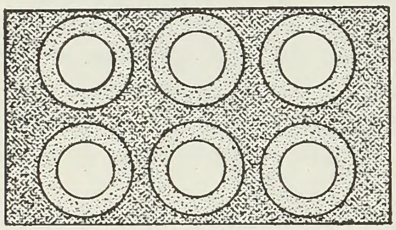
Pattern

Pattern may identify objects.

Open level range with lighter meandering

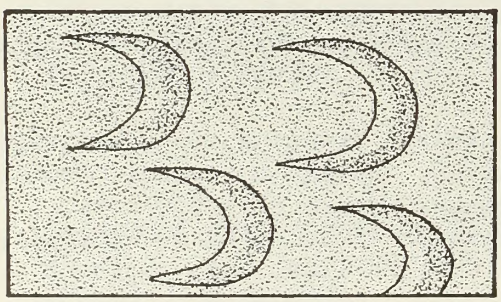


tones converging usually indicates a windmill. Trails and smooth textures from closer grazing gives pattern.

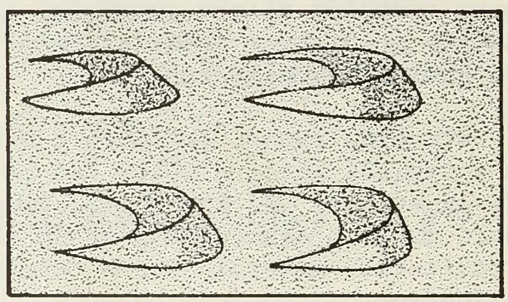


Tanks and surrounding retention dikes indicate oil storage.

Pattern may indicate soil conditions.



Photographic view



Ground view

Very sandy soils or sands migrating over clay sub soil.

Figure···15

Relationship to surrounding objects (Figure 16)

A link must be established in the chain of identification on a photograph. This link is the summation of the relationships of objects on the photograph. The other guides to identification and interpretation sometimes are not enough.

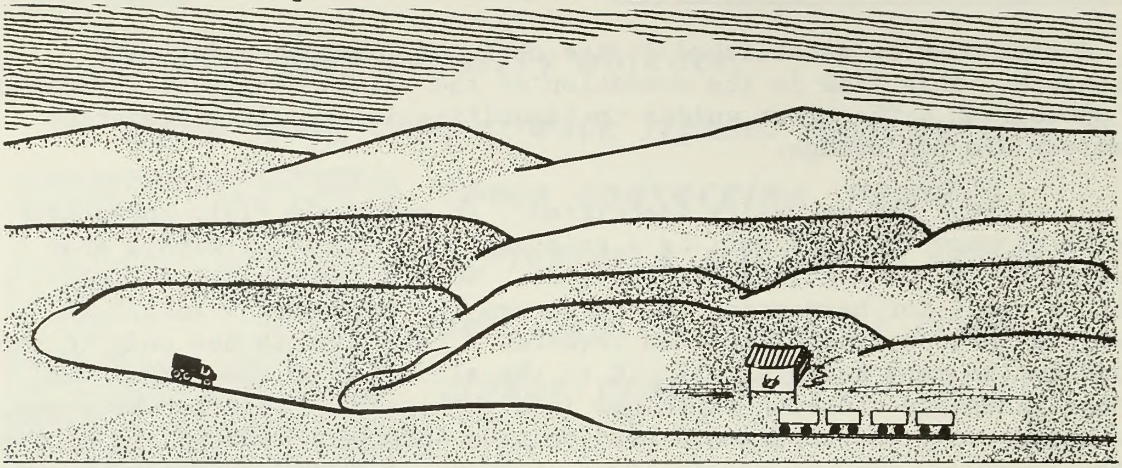
A railroad may be easily identified. It ends in a field abruptly. In time of war, it could well be a railroad gun especially with a spur parallel to it, or a guided missile site. However, a sugarcane field might be ready for harvesting and these are the temporary tracks. The answer is obvious, identification requires a relationship not only to the ground but to many factors implicit to the situation on the ground but perhaps incapable of being expressed in a photograph. This is where you, your background, and experience lead to true interpretation of the photograph.

A broad knowledge of cultural, economic and social factors means much in this phase of interpretation. A simple example is given in Figure 10. A road going to a stream and continuing on the opposite bank, plus the lack of a bridge, is an indication of a ford or a ferry. The parking lot for cars awaiting for the return trip suggests a ferry.

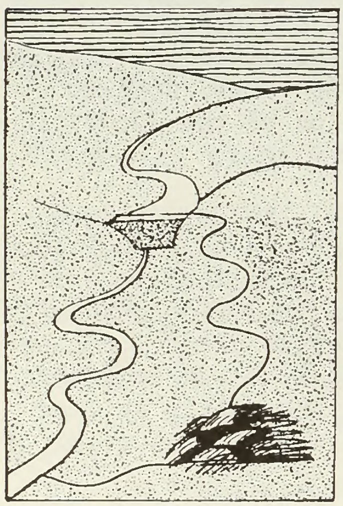
Knowledge of local customs that influence structural design may help. Churches in Europe are oriented toward the east. The direction of the church is determined by the cross-like character of the building--east is at the altar. Customary driving on the roads (left or right) affects construction of cloverleaf intersections--an indication of the unconscious impact of customs of a country on design.

The obvious relationship of railroads to sidings, the abrupt curves of secondary roads, the broad sweep of a super-highway are more than just that. They represent our evaluation of the everyday happenings in our life as we see them, readily recognize the conditions, and relate them to the photograph. If we carry this relationship further in careful evaluation of conditions, not only on manmade features but geological and soil features as well, as a cause and effect, we are entering into the highly skilled field of photo-interpretation where many of the Bureau employees rightfully belong.

Relationship to surrounding objects.



Parallel ridges might be a geological structure but road net leading to railway siding indicates strip mining.



Diversion dam with ditch might be irrigation canal, but ditch is leading to tailings which indicates a flume used in a mining operation.

Sherlock Holmes would enjoy this element particularly in interpreting aerial photographs.

Figure···16

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